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An Analysis of Broadcast Radiation Levels in Hawaii

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Various broadcast installations within Hawaii were examined to determine the potential for hazardous exposure situations in the vicinity of various towers. Power densitys were calculated for each broadcast tower to determine the worst possible exposure situation. Based on the theoretical analysis of possible radiation levels near various broadcast towers in Hawaii, there were no locations where the OSHA occupational standard was exceeded.

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August 1975

U.S. Environmental Protection Agency
Office of Radiation Programs
Washington, DC 20460

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Contents

	Page
Contents	i
List of Tables	ii
List of Figures	iii
Introduction	1
Broadcast Sources	2
Population Estimates	6
Methods and Results of Field Calculations	9
Predicted Levels	21
Standards	24
Conclusions and Recommendations	29
References	33
Appendix	35

List of Tables

Table		Page
1	AM Stations in Honolulu	3
2	FM Stations in Honolulu	4
3	TV Stations in Honolulu	5
4	TV Stations on Hawaii and Maui	7
5	Broadcast Band Allocations and Maximum Authorized Powers	8
6	CEDs, Housing Units and Population Around the KGMB-TV, KHET-TV, KGMQ-FM Broadcast Installation	10
7	CEDs, Housing Units and Population Around the KIKU-TV, KUMU-FM Broadcast Installation	11
8	CEDs, Housing Units and Population Around the KGU, KKUA, KTRG Broadcast Installation	12
9	Calculated Exposures from Honolulu FM and TV Stations	19
10	Calculated Exposures from Hawaii and Maui TV Stations	20
11	Maximum Recommended Levels for Human Exposure	28

List of Figures

Figure		Page
1	Ground Level Field Strength for KGU	13
2	Vertical Radiation Pattern for a UHF-TV Transmitting Antenna	15
3	Power Density and Field Strength in Free Space	17
4	Maximum Power Density as a Function of Distance for Several FM and TV Broadcast Stations in Honolulu . .	25
5	Some Selected Microwave Exposure Standards	26

An Analysis of Broadcast Radiation Levels in Hawaii

Introduction

The Office of Radiation Programs conducts a nationwide program of monitoring and assessment of radiofrequency and microwave radiation levels as they relate to the potential for hazards in the environment. This study was initiated at the request of the Hawaiian State Department of Health and is intended to address the possible harmful radiation effects from broadcast installations in the state of Hawaii. Local news media in Hawaii have carried a number of articles (1-3) pertaining to possible dangers arising from the presence of certain broadcast towers. A State Senate concurrent resolution has instructed the State Health Department to study this question and report its findings by November 1, 1975 (4).

Due to the limited time available and the desire for a rapid analysis, this report is necessarily brief. Additionally, the data on station locations and technical operating parameters have not been subjected to exhaustive verification; consequently the reported inventories of broadcast stations are as accurate as possible but may not be exact. Every effort, within time constraints and reason, has been expended to ensure the maximum reliability of the data and calculations.

The purpose of this report is to theoretically examine the various broadcast installations within Hawaii and to determine the potential for hazardous exposure situations in the vicinity of the various towers.

Most sources of interest are within the city of Honolulu itself, but several are located on other islands. Broadcast radiation safety has been generally examined previously (5) and this report considers predicted field intensities which could exist around different stations. Technical information on station transmitting facilities are used to calculate worst case expected field intensities for AM, FM, and TV stations both at ground level and at elevated locations near towers. Calculated values of exposure are qualitatively evaluated in terms of previous measurement projects at other broadcast stations located on the mainland. The population residing in the vicinity of selected transmitting sites is presented and the results of the field calculations are discussed in terms of RF exposure standards and the potential for associated effects.

Broadcast Sources

An inventory of the various broadcast stations of interest was prepared by referring to a number of different information sources (6-10) as well as reviewing, directly, selected station files at FCC headquarters in Washington, DC. On the basis of this search, listings of stations in Honolulu were prepared and are presented for AM standard broadcast in Table 1, for FM broadcast in Table 2, and television broadcast in Table 3. These tables incorporate the information from all sources above and information supplied by personnel of the State Health Department. There are 17 AM radio stations ranging in transmitter power from 1 to 10 kW, 8 FM radio stations ranging in

Table 1

AM STATIONS IN HONOLULU

CALL	Power (kW)	Freq (kHZ)	Antenna Height (Ft)	LAT (°-'-")	LONG (°-'-")	Effective Field[H/] [mV/m/kW]
KAIM	5	870	220	21-17-08	157-48-08	175 F/
KCCN	5	1420	154	21-19-27	157-52-47	178 G/
KGMB	5	590	270	21-17-59	157-51-33	175 D/
KGU	10	760	270	21-17-41	157-51-49	185 E/
KHAU[A/]	5	-	-	-	-	-
KHVH	5	1040	270	21-17-59	157-51-33	180 D/
KIKI	10	830	270	21-17-59	157-51-33	175 D/
KISA	5	1540	154	21-19-27	157-52-47	183 G/
KKUA	10	690	270	21-17-41	157-51-49	182 E/
KLEI	10	1130	220	21-23-54	157-47-34	191
KNDI	5	1270	182	21-12-29	157-55-59	191
KOHO	5	1170	220	21-17-08	157-48-08	175 F/
KORL	10	650	270	21-17-59	157-51-33	175 D/
KPOI[B/]	5	1380	400	21-17-28	157-50-20	257
KTRG[C/]	5	990	-	21-17-43	157-51-49	-
KUMU	5	1500	220	21-17-08	157-48-08	183 F/
KZOO	1	1210	270	21-17-59	157-51-33	184 D/

A/ Not sure of coordinates.
B/ Present operation; proposed to change to: 21-17-59N, 157-50-20W, with effective field = 203 mV/m/kW, with antenna height of 270 ft.
C/ Not sure whether presently operating.
D/, E/, F/, G/ Stations with same footnote share a common tower.
H/ Field strength at 1 mile per kW input power.

Table 2

FM STATIONS IN HONOLULU

CALL	POWER (kW)	FREQ (MHz)	ANTENNA HEIGHT (FT) ABOVE GROUND	LAT (°-'-")	LONG (°-'-")
KAIM	37	95.5	224	21-17-08	157-48-08 AM
KGMQ[B/]	100	93.1	337	21-17-46	157-50-36 TV
KKAI	25	96.3	70	21-23-57	157-44-46 --
KPOI	35	97.5	400	21-17-28	157-50-20 AM
KTUH[A/]	10 W	90.5	68[C/]/106	21-18-11	157-49-21 --
KULA	60	92.3	245	21-26-43	158-03-49 --
KUMU[B/]	60	94.7	165[C/]/326	21-17-07	157-50-24 TV
KHSS[B/]	100	-	76[C/]/472	-	-

A/Educational.
B/Use circular polarization.
C/Heights above roof where tower is located on a building.

Table 3

TV STATIONS IN HONOLULU

CALL	CHANNEL	POWER (kW) VISUAL	POWER (kW) AURAL	ANTENNA HEIGHT ABOVE GROUND (FT)	LAT (°-'-")	LONG (°-'-")
KHON	2	60.3	12.6	350	21-17-45	157-51-12
KITV	4	100	20	365	21-17-44	157-51-06
KGMB	9	209	29.5	436	21-17-45.7	157-50-35.7
KIKU	13	30.7	6.17	371	21-17-07	157-50-24
KHET	11	148	29.5	436	21-17-45.7	157-50-35.7

effective radiated power (ERP) from 10W (an educational station) to 100 kW which is the maximum authorized power for FM use, and 5 TV stations which range between 37 and 239 kW of ERP. For TV stations both visual and aural ERP is listed. Table 4 lists the TV stations in other parts of Hawaii. The height of the transmitting antenna above ground is given for TV stations, while for FM stations the antenna height above roof level is also shown when the tower is located on a building rather than on the ground. Table 5 gives the band allocations for the various broadcast services and maximum authorized powers which may be used by some stations. There are no UHF TV stations in the state of Hawaii.

A number of stations in Honolulu share common towers for their antennas or antenna supports. Of the 30 stations listed within Honolulu there are apparently only 16 physically separate locations for transmitting antennas. For example, five different AM stations share a single common tower in their operations and at one location two TV stations and one FM station share the use of a common tower. Honolulu has a large number of tall buildings of nearly equal height with broadcast antennas atop several of them. This is not a unique situation when compared to some other metropolitan areas on the mainland.

Population Estimates

Coupled with the relatively high density of broadcast installations is a relatively high population density in the immediate Honolulu area. As a means of establishing the population in the area of interest, the population was estimated around three tower sites using a computerized

Table 4

TV Stations on Hawaii

Call	Channel	Power (kW) Visual	Power (kW) Aural	Antenna Height Above Ground (Ft)	Lat (°-'-")	Long (°-'-")
KHAW	11	2.09	0.275	80	19-43-56	155-04-09
KHVO	13	4.68	1.59	80	19-43-57	155-04-04
KPUA	9	1.00	0.50	258	19-43-00	155-08-13

TV Stations on Maui

KAII	7	29.8	5.89	75	20-42-41	156-15-26
KMAU	3	14.1	2.69	60	20-42-41	156-15-35
KMVI	12	30.0	4.36	100	20-42-43	156-15-26
KMEB	10	30.9	6.17	47	20-42-40	156-15-34

Table 5

Broadcast Band Allocations and Maximum Authorized Powers

Service	Frequency Range (MHz)	Maximum Authorized Power (kW)
Am Standard Broadcast	0.55-1.6	50
FM	88-108	100*
Low VHF TV	54-88	100
High VHF TV	174-216	316
UHF TV	490-893	5000

*In each polarization plane.

census data base. This method has been used previously (11) to determine population exposure to AM radio stations. In this case, the population residing within given distances out to a maximum range of 5 miles was computed for three broadcast locations: (a) the KGMB-TV, KHET-TV, and KGMQ-FM site, (b) the KIKU-TV and KUMU-FM site, and (c) the KGU AM radio site. Table 6 presents the number of census enumeration districts (CEDs), the number of housing units, and the total population computed via the program for site (a) above. Tables 7 and 8 provide similar data for sites (b) and (c). These estimates show populations of 41,363, 28,610, and 2,449 residing within one mile of sites a, b, and c above. Population values based on a small number of CEDs must be considered approximate but values associated with more than 10 CEDs are probably quite accurate. These population numbers do

not include transient fluctuations which occur during the day nor nonresidents.

Methods and Results of Field Calculations

AM Standard Broadcast

AM radio stations employ vertical polarization in transmission using vertical towers typically situated over ground, but infrequently, towers are located on building roofs. The entire tower is the radiating element in AM broadcast and produces a ground wave field at locations about it. All AM stations in Hawaii utilize single monopole types of antennas and have non-directional radiation patterns. Based on the tower's height, the transmitter output power, and ground conductivity at the assigned frequency, the electric field strength can be computed via analytical techniques. Using one such technique (12) the ground level field strength was computed for KGU AM and is shown in Figure 1 as a function of distance out to 5 km. At the point of minimum distance for which calculations were made (100 meters) a field strength of 9.3 V/m was found. Because at one location, indicated by footnote D in Table 1, 5 stations use the same tower, a maximum expected equivalent power density was computed as 57.8 $\mu W/cm^2$. In this computation the five 5 kW stations have been assumed to have an effective field at one mile of 185 mV/m/kW and to be on a frequency of 760 kHz with a ground conductivity of 15 m mhos/m, with a 270' high tower.

FM and TV Transmissions

FM and TV stations normally employ transmitting antennas which

Table 6

CEDs, Housing Units and Population Around the KGMB-TV, KHET-TV, KGMQ-FM Broadcast Installation[A/]

Miles	CEDs	Housing Units	Population
0.1	1	383	765
0.2	2	547	1170
0.3	5	1750	3323
0.4	8	2796	5942
0.5	15	5983	11990
0.6	20	8855	18765
0.7	22	9301	19894
0.8	31	13107	28134
0.9	38	15542	33810
1.0	46	19160	41363
1.5	78	32170	72472
2.0	107	42312	99572
2.5	140	52240	131078
3.0	186	64008	172740
3.5	213	73312	206932
4.0	244	82463	242636
4.5	255	86382	258346
5.0	262	88271	266664

A/Based on 1970 Census data.

Table 7

CEDs, Housing Units and Population Around the KIKU-TV, KUMU-FM Broadcast Installation[A/]

Miles	CEDs	Housing Units	Population
0.1	0	0	0
0.2	0	0	0
0.3	1	0	47
0.4	5	2138	3415
0.5	9	3659	5882
0.6	12	5070	8373
0.7	15	6155	10579
0.8	20	8029	15416
0.9	24	10138	20344
1.0	33	14195	28610
1.5	59	24798	54757
2.0	99	39972	94303
2.5	130	48233	119751
3.0	165	59025	154544
3.5	202	69854	193322
4.0	221	75743	215180
4.5	236	80909	234476
5.0	256	86239	256834

[A/]Based on 1970 Census data.

Table 8

CEDs, Housing Units and Population Around the KGU, KKUA, KTRG Broadcast Installation[A/]

Miles	CEDs	Housing Units	Population
0.1	0	0	0
0.2	1	0	314
0.3	1	0	314
0.4	1	0	314
0.5	2	279	837
0.6	2	279	837
0.7	2	279	837
0.8	3	1025	2186
0.9	4	1144	2449
1.0	4	1144	2449
1.5	26	9424	19423
2.0	68	25439	54228
2.5	109	39894	96006
3.0	147	53239	137943
3.5	176	62502	170515
4.0	213	72362	206644
4.5	243	80879	240464
5.0	262	88122	268496

[A/]Based on 1970 Census data.

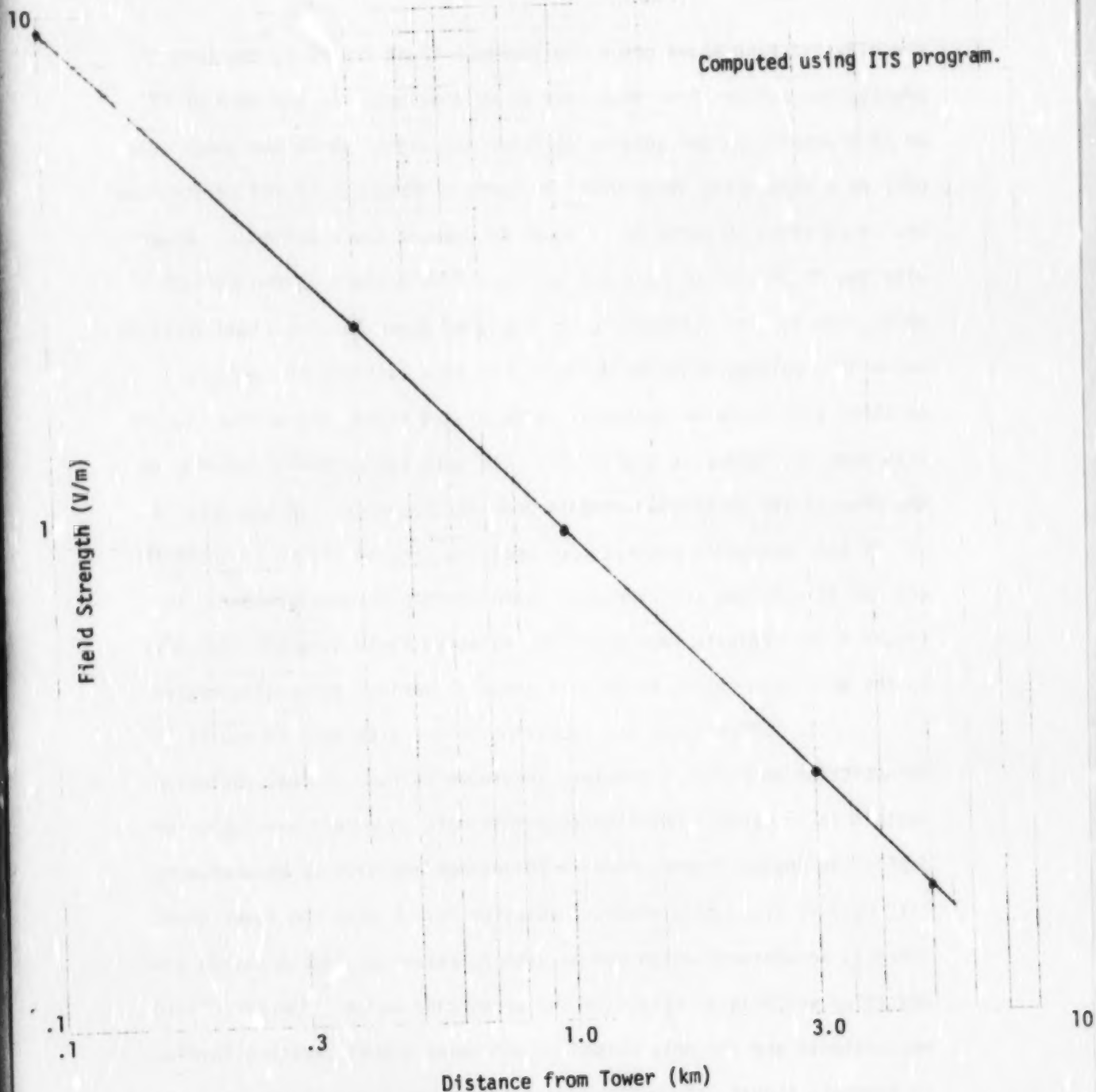

Figure 1 Ground Level Field Strength for KGU, Honolulu, Hawaii
10 kW, 760 kHz, ε=15, σ=15, Tower Height=270', Vertical Polarization

are elevated high above ground to increase their coverage; the mode of propagation differs from that used by AM stations. In the case of FM or TV transmission the antenna radiates the signal while the tower acts only as a supporting structure. In certain instances FM and TV stations use an existing AM radio or TV tower to support their antennas. Generally the FM and TV antennas exhibit a uniform pattern in the azimuth while they tend to concentrate the radiated power in a confined vertical beamwidth, pointed near the horizon. In this fashion, the antenna exhibits gain above an isotropic radiator and allows the station to use less power to produce a higher ERP. The vertical beamwidth depends on the size of the particular antenna and the frequency. In the case of UHF TV this beamwidth becomes very small as seen in Figure 2. With FM and VHF TV antennas this vertical plane pattern becomes broader. In Figure 2 the ordinate represents the relative field strength (relative to the main beam value) which will occur at various depression angles.

To fully assess the radiation intensities near FM and TV transmitting antennas, a complete knowledge of the vertical radiation pattern is required. Unfortunately this data is rarely available for depression angles greater than 15-20 degrees and thus it becomes very difficult to accurately compute radiation levels near the tower base. There is an approach which can be used to assess maximum possible power densities which is to calculate the worst case value. However, field measurements are the only method to determine actual exposure levels. In general, though, the maximum, worst case level calculated will not be exceeded.

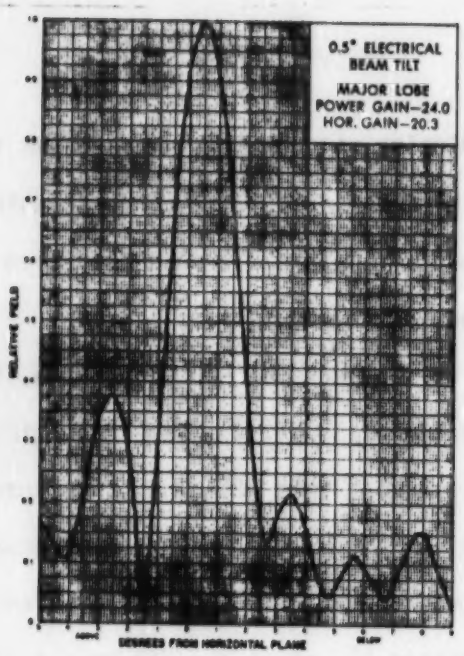

Figure 2 Vertical Radiation Pattern for a UHF-TV Transmitting Antenna

The power density in the main beam of an FM or TV installation may be computed as follows:

$$W\ (mW/cm^2) = \frac{ERP}{40\pi R^2}$$

where

ERP is the main beam effective radiated power in watts

R is the distance from the antenna in meters

Another convenient formula for computing the electric field strength of a station is

$$E\ (V/m) = \frac{\sqrt{30ERP}}{R}$$

When the vertical radiation pattern is known the ERP in the desired direction should be substituted into the above formulas. In the absence of the vertical pattern the maximum ERP has been used to compute power densities for the Hawaiian FM and TV stations.

Also, when measurements are not available, to assist in the hazard analysis, it must be assumed that the formation of standing wave patterns is possible and that this effect will increase the apparent radiation exposure level. It is conventional to assume that a reflected wave can add constructively with the incident wave and double the electric field strength or increase the power density by a factor of four (13). Power density and field strength are related by

$$W\ (W/m^2) = \frac{E\ (V/m)^2}{120\pi\Omega} \quad \text{where}$$

120π represents the impedance of free space. Figure 3 illustrates this relationship graphically. Thus, calculated main beam power densities must be increased by 6 dB (a factor of 4) to account for possible multipath effects on signal enhancement.

Generally the radiation pattern at extremely steep depression angles, for example near 90° or straight down the tower, implies a very low level of radiation relative to the main beam. However, it has been observed, via field measurements, that intense levels of RF may occur

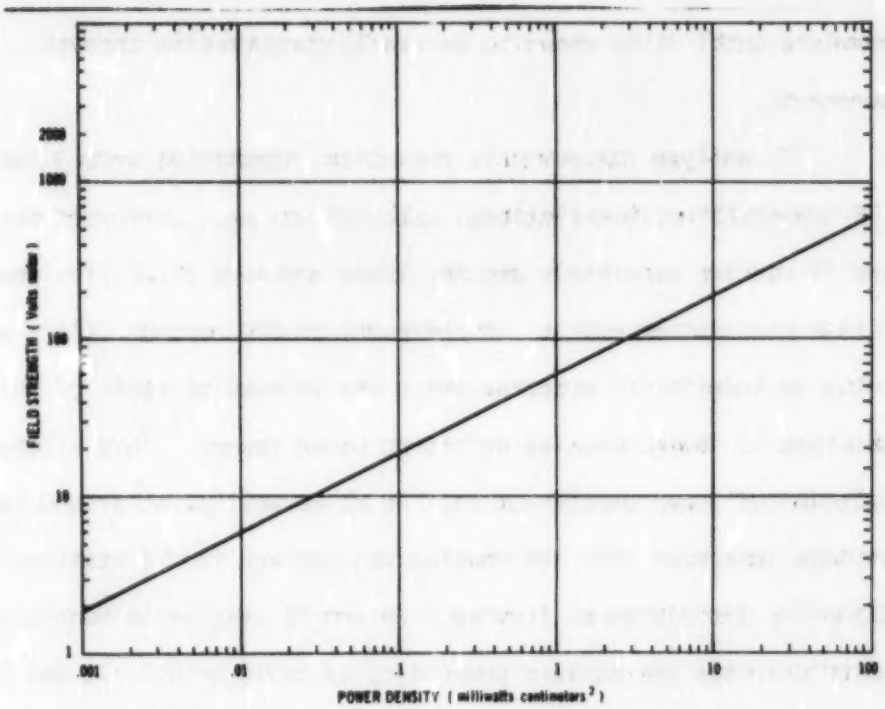

Figure 3 Field Strength and Power Density in Free Space

near the base of certain FM transmitting antennas (14) contrary to the simple theory. This steep angle radiation is presumably due to the particular configuration of radiating elements on various types of antennas. It is not clear whether this phenomena exists for commonly used VHF TV transmitting antennas or not. However, in the absence of any definitive measurement data on TV antennas it is assumed, for the purposes of this report, that VHF TV as well as FM antennas can exhibit

this property. For a potential hazards analysis this assumption seems appropriate until it is shown to be overly conservative through measurements.

To analyze the possible radiation intensities around the FM and TV transmitting installations, calculations were performed for each FM and TV station separately and for those combined facilities where more than one station exists. By referral to FCC records (7) it was possible to identify FM antennas which are located on roofs of buildings in addition to those situated on ground based towers. This allowed the calculation of power density at roof level as well as at ground level. In certain instances this information was derived for TV stations also. Additionally the distances from each FM and TV station in Honolulu were computed at which the maximum power density could be 0.1, 1, and 10 mW/cm^2. All of this data is presented in Table 9 for Honolulu stations. Table 10 contains similar data for other TV stations in the state. Until data on actual radiation patterns is available the distances listed for given exposures in Tables 9 and 10 must be considered as applicable at any vertical angle from the transmitting antenna and can be used to establish areas in which the exposure level may be as high as the given value. For FM stations the roof and/or ground level values have been computed using the ERP in the horizontal plane only since experience has shown that the vertically polarized field is very low in comparison to the horizontal component at steep depression angles. For the calculation of distance to various power densities for FM stations,

Table 9

Calculated Exposures from Honolulu FM and TV Stations[A/]

Call	Power (kW)	Distance (ft) to following power densities (mW/cm^2) 0.1	1.0	10.0	Power Density at Roof level and/or ground level[C/] (mW/cm^2)
KAIM	37	356	112.6	35.6	0.253
KGMQ[B/]	100	828	261	82.8	0.302
KHSS[B/]	100	828	261	82.8	5.93/0.154
KPOI	35	346	109.4	34.6	0.075
KTUH	10W	6	1.8	-	-
KUMU[B/]	60	641	203	64.1	0.755/0.193
KKAI	25	293	92.6	29.3	1.747
KULA	60	453	143	45.3	0.342
KHON-TV	72.9	491	165	49.1	0.204
KITV-TV	120	641	203	64.1	0.308
KGMB-TV	238.5	904	286	90.4	0.430
KIKU-TV	36.9	355	112	35.5	0.301/0.092
KHET-TV	177.5	780	247	78.0	0.320
KGMB-TV, KHET-TV, KGMQ-FM	616	1452	459	145	1.052
KIKU-TV, KUMU-FM	156.9	733	232	73.3	1.056/0.285

A/Calculations employ main beam ERP and assume that the resultant field strength is twice the simply computed free space value.
B/Uses circular polarization.
C/Figures to left of a slash indicate roof level power densities.

Table 10

Calculated Exposures from Hawaii and Maui TV Stations[A/]

Call	Power (kW)	Distance (ft) to following power densities (mW/cm^2) 0.1	1.0	10.0	Power Density at Roof level and/or ground level (mW/cm^2)
Hawaii					
KHAW-TV	2.365	90.0	28.5	9.00	0.13
KHVO-TV	6.27	147	46.3	14.7	0.34
KPUA-TV	1.50	71.7	22.7	7.17	0.01
Maui					
KAII-TV	35.69	350	111	35.0	2.17
KMAU-TV	16.79	240	75.8	24.0	1.60
KMVI-TV	34.36	343	108	34.3	1.18
KMEB-TV	37.07	356	113	35.6	5.75

A/Calculations employ main beam ERP and assume that the resultant field strength is twice the simply computed free space value.

the power in both polarization planes has been used since at locations lateral to the tower both components would add.

To properly assess the implications of these distances with respect to adjacent building exposure, a complete knowledge of building heights and locations is required. Information on some of the taller buildings in Honolulu was provided by the State Health Department and has been used to investigate situations where individuals might be exposed to relatively intense RF fields. The data on buildings was not necessarily complete, and the possibility remains that there exist other locations not considered here where significant power densities occur.

A simple approach for identifying areas subject to the specified, maximum possible power densities is to envision a spherical surface centered on the various transmitting antennas with a radius equal to the distance associated with a given exposure level. The intersection of this spherical surface with nearby buildings can be used to isolate specific areas of interest for more detailed analysis.

Predicted Levels

Inspection of Table 9 reveals that a computed power density as high as 6 mW/cm^2 may exist on the roof of the Ala Moana Hotel which supports the KHSS-FM transmitting antenna. A power density of 1.052 mW/cm^2 is found at the base of the KGMB-TV tower. In the case of multiple station outlets the computed power density is found by adding all station powers together. A ground level value of 1.7 mW/cm^2 is predicted at

the base of the KKAI-FM tower. In general, the values of power density found at either roof level, or ground level are found to be in the vicinity of 1 mW/cm^2 or lower while at three locations the computed values are above 1 mW/cm^2 and one is near 6 mW/cm^2. At no location is the roof or ground level power density found to exceed 10 mW/cm^2.

Table 10 shows that maximum power densities of 0.01 to 5.75 mW/cm^2 may exist near the tower bases of TV stations located on the islands of Hawaii and Maui. Generally the highest power densities computed are associated with relatively low antenna heights and relatively high power. Low antenna heights are usually associated with an installation on a tall building or mountain top where the antenna is normally elevated just enough to avoid clutter in the immediate area; this clutter might be air conditioning equipment or elevator shafts on a tall building or trees on a mountain top. In such cases, it would not be unusual for access to the base of the tower to be restricted, as on a roof, or infrequently visited as on a remote mountain top.

Because of the difficulty in obtaining complete information on building heights the following comments are presented on specific building locations and associated exposure levels in order of decreasing areas of interest:

- Ala Moana Hotel - This is the site of KHSS-FM located on the roof with a 76' tower. Power densities on the roof could approach 6 mW/cm^2. This station could possibly provide the highest proportion of total exposure on the roof of the adjacent Ala Moana Building at 1441

Kapiolani Blvd. This roof at 300 feet above ground could experience a power density of 0.4 mW/cm^2 assuming that it is not more than 400 feet away from the KHSS-FM antenna site.

- KMEB-TV tower on Maui - This is the location of the lowest antenna for any FM or TV broadcast station in the state. Coupled with 37 kW of ERP the ground level power density could possibly reach 5.75 mW/cm^2.

- KAII-TV and KMAU-TV towers on Maui - These two towers are close to the ground and located within 0.1 mile of each other on Mt. Haleakala. Ground level power densities of 2.2 and 1.6 mW/cm^2 were computed for KAII and KMAU, respectively.

- KKAI-FM - Apparently located on a hill side with a 70' antenna height, this station could produce a ground level power density at the foot of the tower of 1.7 mW/cm^2.

- KGMB-TV, KHET-TV, and KGMQ-FM - This transmitter site has the highest concentration of ERP of any location within the state. A ground level power density of 1.05 mW/cm^2 was computed at the base of the 365' tower which supports the antennas for the three stations.

- KMVI-TV tower on Maui - The antenna is 100' above ground on Haleakala Crater and could produce a ground level power density of 1.2 mW/cm^2.

• Hawaiian Village Hotel - This is the site of the KIKU-TV and KUMU-FM antenna tower at 371' above ground. A roof level power density of 1.05 mW/cm^2 and ground levels of 0.29 mW/cm^2 are predicted.

A number of other building locations could be in areas at which power densities in the range of 0.1 and 1 mW/cm^2 could occur but definite information on their distance from nearby towers is necessary. Figure 4 is a graph of maximum power density from several of the more powerful emitters in the source inventory vs. distance away in the main beam.

Standards

Currently the only Federal RF standards in the U.S. are the Occupational Safety and Health Administration (OSHA) standard (14) for occupational exposure control and the Bureau of Radiological Health (BRH) microwave oven performance standard (15). The OSHA standard is 10 mW/cm^2 as averaged over any possible 0.1 hour period. This means the following:

Power density: 10 mW/cm^2 for periods of 0.1 hour or more

Energy density: 1 $mW\text{-}hr/cm^2$ during any 0.1 hour period.

The BRH microwave oven standard specifies that any microwave oven must not leak radiation exceeding a power density of 5 mW/cm^2 at any point two inches from the surface during the life time of the oven. Figure 5 illustrates the exposures allowed for various durations by different exposure guides.

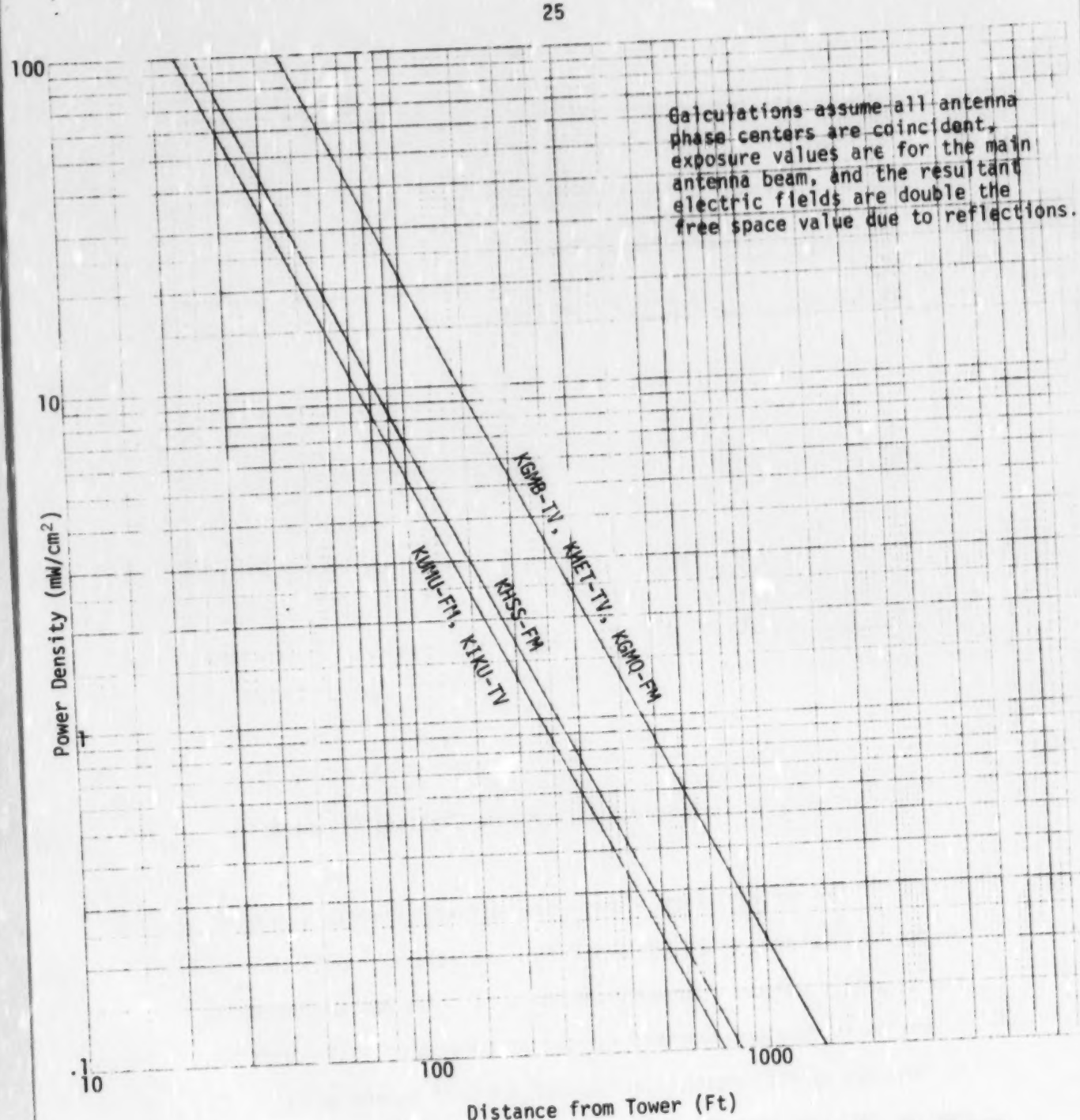

Figure 4 Maximum Power Density as a Function of Distance for Several FM and TV Broadcast Stations in Honolulu

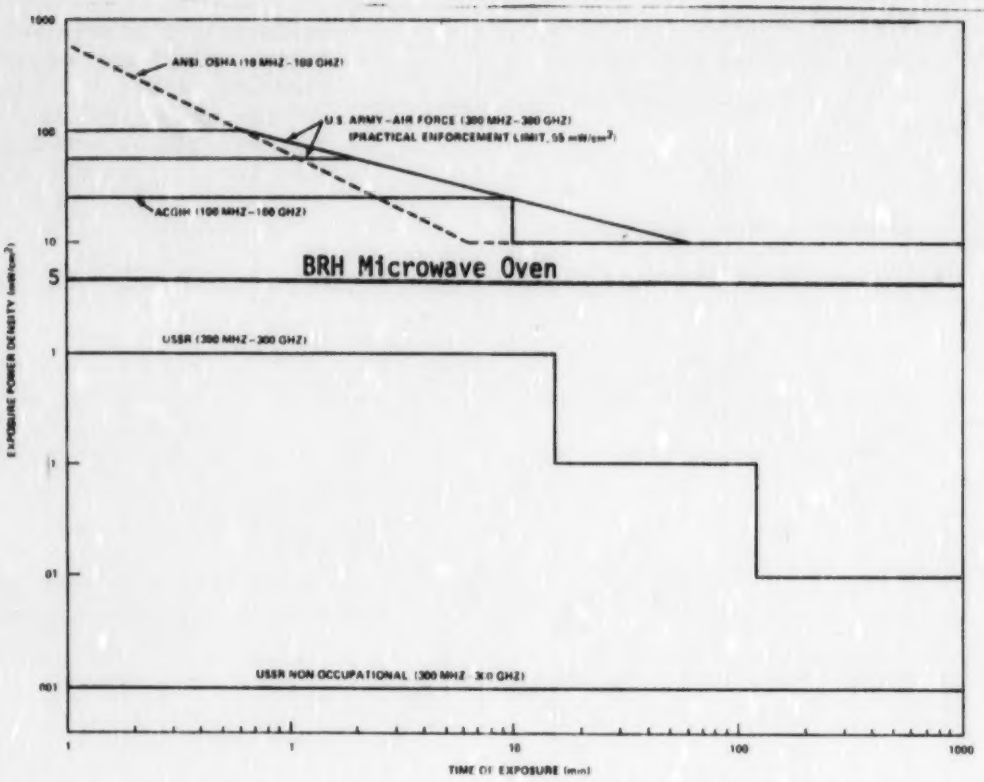

Figure 5 Some Selected Microwave Exposure Standards

The standards are either occupational exposure standards or product performance standards and are not necessarily applicable to the general populace. However, the State of Texas has announced its intention to develop standards for the protection of individuals and is structuring its proposal in terms of the OSHA standards (16). It must be realized that the OSHA standard implies the ability to control

the exposure to workers and assumes prior knowledge of the health conditions of workers. The health conditions of individuals and the number of exposed must be taken into account and the overall impact on potential risk evaluated before establishing a generally applicable environmental RF exposure standard. At the present stage of evaluation, exposure levels over 10 mW/cm^2 are considered as potentially hazardous and should be reduced.

Exposure levels between 1 and 10 mW/cm^2 are considered as significant and such exposure situations should be documented in the event that research indicates that a limiting criteria should be established somewhere in this range. Exposure levels below 1 mW/cm^2 are rather prominent in the environment and at the present time there is no scientific evidence of them being a hazard.

Other factors besides direct biological interactions must be considered in evaluating RF hazards. A potentially important factor is radiofrequency interference to various electronic equipments, particularly critical life support devices such as cardiac pacers and medical products used in hospitals. Interference to pacemaker operation has been clinically observed from at least one patient due to a UHF-TV broadcast installation (18) and an inside-the-hospital standard of 1 V/m (0.26 $\mu W/cm^2$) has been established in the University of California Medical Center (19) due to the close proximity of a high power broadcast installation. Table 11 illustrates some of the various RF exposure standards and points out the wide difference between these

Table 11

Some RF/Microwave Exposure Standards

Standard	Applicable Frequency Range	Limits and Comments	
OSHA	10 MHz - 100 GHz	10 mW/cm^2 for periods >0.1 hour 1 $mW\text{-}hr/cm^2$ during any 0.1 hour period	
ANSI	10 MHz - 100 GHZ	Same as OSHA but includes other specifications for field as 40,000 V^2/m^2 or 0.25 A^2/m^2	
BRH	915, 2450	5 mW/cm^2 at any point two inches from surface of microwave oven during life time	
USAF	300 MHz - 300 GHz	$T = 6,000/W^2$ where T is time of exposure permitted and W is power density in mW/cm^2	
	10 kHz - 10 MHz	50 mW/cm^2 for periods >6 min 18,000 $mW\text{-}sec/cm^2$ for periods <6 min 100 kV/m peak pulse, 1 pulse/minute	
USSR		Occupational Groups	The Population
	Medium Waves	50 V/m	10 V/m
	100 kHz - 3 MHz	5 V/m	Not Established
	3 - 30 MHz	20 V/m	4 V/m
	30 - 50 MHz	10 V/m	1 V/m
	50 - 300 MHz	5 V/m	Not Established
	0.3 - 300 GHZ	10 $\mu W/cm^2$	1 $\mu W/cm^2$

standards in the U.S. and similar ones in the USSR.

Conclusions and Recommendations

On the basis of a theoretical analysis of possible radiation levels near various broadcast towers in Hawaii, there are no locations where the OSHA standard is exceeded. The principal sources of high intensity RF exposure are the FM radio and TV stations as opposed to the AM radio stations. It appears that specific locations may be subject to exposures in the 1 to 10 mW/cm^2 range depending on the particular geometry of the antenna, building, and local terrain. Power densities in this range are probably limited to the immediate area about the base of the installations in question, be it on a roof or at ground level beneath a short tower. There may exist numerous unrestricted areas in which individuals may experience exposures of about 1 mW/cm^2, this being 0.1 of the OSHA guide. Radiation at steep depression angles has been recently observed at other broadcast stations (20,21) and represents a unique aspect of the overall hazard evaluation in that the intensity due to this steep angle radiation is not calculable with accuracy.

The effects of building attenuation are difficult to assess theoretically but will, in general, produce substantial reductions in exposure. It is possible, though, that due to standing wave formation with a glassed-in area, the inside field intensity could equal the calculated values just outside the glassed area.

Local field strengths from AM standard broadcast stations are less potentially hazardous because of their much lower frequency and lower amplitudes. The possibility of RF voltage induction in very nearby conductors may prove undesirable from the standpoint of interference, RF shocks, or detonation of electroexplosives (22).

RF levels in the near vicinity of FM and TV stations, whether on the roof or in adjacent buildings, are of sufficient intensity to be a potential source of interference to critical medical devices such as pacemakers.

The distribution of broadcast installations in Honolulu suggests that there will not be areas where biologically hazardous (>10 mW/cm^2) field intensities could exist due to the multiple source environment.

There appears to be no frankly hazardous exposure situations possible, but there is the possibility of certain areas where the power density clearly could exceed 1/10 of the OSHA standard. This situation may not be substantially different from a number of other metropolitan areas where the boradcast source density is high and tall buildings predominate. The Honolulu area may represent a somewhat unusual exposure situation in that there exist several high power FM stations on buildings near which adjacent buildings are approximately the same height. Generally in broadcast installations on tall buildings, the ERP is limited to minimize the potential for interference to distant FM stations using the same frequency.

The validity of the calculational approach used in this report needs to be evaluated by making field measurements at the base of VHF TV and FM towers and comparing these measurements with theoretical results. Such a field measurement program is being conducted by EPA. In conjunction with ambient, broad frequency range, electromagnetic radiation exposure level measurements using a specially developed monitoring van, measurements on roof tops and at tower bases in major metropolitan areas on a specific source basis has been initiated. Limited EPA measurement data has verified the unexpected high intensity steep angle beam from some FM stations, but these measured values do not exceed worst case calculated values. Until the measurements are completed it must be assumed that the steep angle radiation phenomena from some FM broadcast stations may also be characteristic of VHF TV antennas.

In summary, based on the data provided and conservative assumptions, none of the calculated values exceeds 10 mW/cm^2, the OSHA standard for occupational exposure. There are several locations where there is a possibility for exposure in the 1 to 10 mW/cm^2 range. The population subject to exposure levels in this range is not well defined but is probably very small. While these levels are of interest because they are within a factor of 10 of the occupational standard and need to be documented for future standard considerations, we would not recommend that any action be taken at the present time. The model used to calculate the exposure levels at steep depression angles in the

immediate vicinity of FM and VHF television antennas needs additional investigation through actual measurements. This model investigation is incorporated into current field study plans and we have uncovered nothing unique about the antennas or their siting that would dictate that the planned measurements should be done in Hawaii as opposed to some other more convenient site.

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Appendix

VOLTAGE AND POWER RATIOS TO dB

VOLTAGE RATIO	POWER RATIO	dB	VOLTAGE RATIO	POWER RATIO	VOLTAGE RATIO	POWER RATIO	dB	VOLTAGE RATIO	POWER RATIO
1.0000	1.0000	0.00	1.0000	1.0000	.5179	.2630	5.8	1.930	3.802
.9954	.9977	0.01	1.0012	1.0023	.5070	.2570	5.9	1.972	3.890
.9908	.9954	0.02	1.0023	1.0046	.5012	.2512	6.0	1.995	3.981
.9863	.9931	0.03	1.0035	1.0069	.4955	.2455	6.1	2.018	4.074
.9816	.9908	0.04	1.0046	1.0093	.4898	.2399	6.2	2.042	4.169
.9761	.9886	0.05	1.0058	1.0116	.4842	.2344	6.3	2.065	4.266
.9705	.9863	0.06	1.0069	1.0139	.4786	.2291	6.4	2.089	4.365
.9705	.9840	0.07	1.0081	1.0162	.4732	.2239	6.5	2.113	4.467
.9608	.9817	0.08	1.0093	1.0186	.4677	.2188	6.6	2.138	4.571
.9607	.9795	0.09	1.0104	1.0209	.4624	.2138	6.7	2.163	4.677
.9556	.9772	0.1	1.0012	1.0233	.4571	.2089	6.8	2.188	4.786
.9772	.9750	0.2	1.0023	1.0467	.4519	.2042	6.9	2.213	4.898
.9611	.9133	0.3	1.0035	1.0702	.4467	.1995	7.0	2.239	5.012
.9550	.9120	0.4	1.0047	1.0936	.4416	.1950	7.1	2.265	5.129
.9441	.9113	0.5	1.0059	1.1223	.4365	.1905	7.2	2.291	5.248
.9333	.8710	0.6	1.0072	1.1468	.4315	.1862	7.3	2.317	5.370
.9226	.8511	0.7	1.0084	1.1715	.4266	.1820	7.4	2.344	5.495
.9120	.8318	0.8	1.0096	1.1962	.4217	.1778	7.5	2.371	5.623
.9016	.8128	0.9	1.0109	1.2210	.4169	.1738	7.6	2.399	5.754
.8913	.7943	1.0	1.0122	1.2459	.4121	.1698	7.7	2.427	5.888
.8810	.7762	1.1	1.0135	1.2708	.4074	.1660	7.8	2.455	6.026
.8710	.7586	1.2	1.0148	1.2958	.4027	.1622	7.9	2.483	6.166
.8610	.7413	1.3	1.0161	1.3209	.3981	.1585	8.0	2.512	6.310
.8511	.7244	1.4	1.0175	1.3460	.3936	.1549	8.1	2.541	6.457
.8414	.7079	1.5	1.0189	1.3712	.3890	.1514	8.2	2.570	6.607
.8318	.6918	1.6	1.0202	1.3965	.3846	.1479	8.3	2.600	6.761
.8222	.6761	1.7	1.0216	1.4219	.3802	.1445	8.4	2.630	6.918
.8128	.6607	1.8	1.0230	1.4474	.3758	.1413	8.5	2.661	7.079
.8035	.6457	1.9	1.0245	1.4729	.3715	.1380	8.6	2.692	7.244
.7943	.6310	2.0	1.0259	1.4985	.3673	.1349	8.7	2.723	7.413
.7852	.6166	2.1	1.0274	1.5242	.3631	.1318	8.8	2.754	7.586
.7762	.6026	2.2	1.0288	1.5500	.3589	.1288	8.9	2.786	7.762
.7674	.5888	2.3	1.0303	1.5758	.3548	.1259	9.0	2.818	7.943
.7586	.5754	2.4	1.0318	1.6218	.3508	.1230	9.1	2.851	8.128
.7499	.5623	2.5	1.0334	1.6578	.3467	.1202	9.2	2.884	8.318
.7413	.5495	2.6	1.0349	1.6839	.3428	.1175	9.3	2.917	8.511
.7328	.5370	2.7	1.0365	1.7102	.3388	.1148	9.4	2.951	8.710
.7244	.5248	2.8	1.0380	1.7365	.3350	.1122	9.5	2.985	8.913
.7161	.5129	2.9	1.0396	1.7628	.3311	.1096	9.6	3.020	9.120
.7079	.5012	3.0	1.0413	1.7893	.3273	.1072	9.7	3.055	9.333
.6998	.4898	3.1	1.0429	2.0542	.3236	.1047	9.8	3.090	9.550
.6918	.4786	3.2	1.0445	2.1209	.3199	.1023	9.9	3.126	9.772
.6839	.4677	3.3	1.0462	2.1138	.3162	.1000	10.0	3.162	10.000
.6761	.4571	3.4	1.0479	2.1808	.3981	.0891-3	10.5	3.548	12.59
.6683	.4467	3.5	1.0496	2.2339	.7943	.0794	11.0	3.548	12.59
.6607	.4365	3.6	1.0514	2.2911	.7661	.07079	11.5	3.758	14.13
.6531	.4266	3.7	1.0531	2.3444	.7412	.06310	12.0	3.981	15.85
.6457	.4169	3.8	1.0549	2.3999	.7371	.05623	12.5	4.217	17.78
.6383	.4074	3.9	1.0567	2.4555	.7239	.05012	13.0	4.467	19.95
.6310	.3981	4.0	1.0585	2.5122	.7113	.04467	13.5	4.732	22.39
.6237	.3890	4.1	1.0603	2.5702	.7995	.02981	14.0	5.012	25.12
.6166	.3802	4.2	1.0622	2.6302	.7884	.03548	14.5	5.309	28.18
.6095	.3715	4.3	1.0641	2.6923	.7778	.03162	15.0	5.623	31.62
.6026	.3631	4.4	1.0660	2.7546	.7585	.02512	16.0	6.310	39.81
.5957	.3548	4.5	1.0679	2.8184	.7413	.01995	17.0	7.079	50.12
.5888	.3467	4.6	1.0698	2.8864	.7759	.01585	18.0	7.943	63.10
.5821	.3388	4.7	1.0718	2.9511	.7122	.01259	19.0	8.913	79.43
.5754	.3311	4.8	1.0738	3.0200	.7000	.01000	20.0	10.000	100.00
.5689	.3236	4.9	1.0758	3.0900	.03162	.00100	30.0	31.620	1,000.00
.5623	.3162	5.0	1.0778	3.1623	.01	.00010	40.0	100.00	10,000.00
.5559	.3090	5.1	1.0799	3.2359	.003162	.00001	50.0	316.20	10^5
.5495	.3020	5.2	1.0820	3.3113	.001	10^{-6}	60.0	1,000.00	10^6
.5433	.2951	5.3	1.0841	3.3884	.0003162	10^{-7}	70.0	3,162.00	10^7
.5370	.2884	5.4	1.0863	3.4677	.0001	10^{-8}	80.0	10,000.00	10^8
.5309	.2818	5.5	1.0884	3.5481	.00003162	10^{-9}	90.0	31,620.00	10^9
.5248	.2754	5.6	1.0905	3.6308	10^{-4}	10^{-10}	100.0	10^5	10^{10}
.5188	.2692	5.7	1.0928	3.7154					